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Baker

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March 24, 1999

Commander
Atlantic Division
Naval Facilities Engineering Command
1510 Gilbert Street (Building N-26)
Norfolk, Virginia 23511-2699

Attn: Mr. Robert Schirmer, P.E.
Code 18222

Re: Contract N62470-89-D-4814
Navy CLEAN, District III
Contract Task Order (CTO) 0388
Draft Field Investigation Report - Site 1 and Area of Concern 2
Fleet and Industrial Supply Center
Cheatham Annex, Williamsburg, Virginia

Dear Mr. Schirmer:

Baker Environmental, Inc. (Baker) is pleased to submit two copies of the Field Investigation Report for Site 1-Landfill near Incinerator and Area of Concern (AOC) 2 - Dextrose Dump at the Fleet and Industrial Supply Center (FISC), Cheatham Annex, Williamsburg, Virginia

The enclosed document summarizes the findings of the Field Investigation which was performed in October 1998 and also presents recommendations for the future management of Site 1 and AOC 2. On October 15, 1999, Baker visited Site 1 to view the clearing activities that are being completed as an interim measure to curtail erosion of the bank of the York River adjacent to the Landfill. During this site visit Baker observed that along the upstream edge of the landfill, a thin layer of debris outcrops just below the ground surface indicating that the landfill extends to the bank of the York River for a distance of approximately 25-feet along the river. The bank varies in height from approximately 2 to 10 feet in this area and it is being actively eroded with apparent landfill debris (sparsely) present on the beach in this area. A rusted 5-gallon pail which contains an unidentified yellow substance outcrops from the bank in this area.

In Section 6.0 of the enclosed Field Investigation Report, Baker recommends that immediate measures be taken to prevent the ongoing erosion of the bank in the vicinity of the debris outcropping. Potential measures to consider include installation of rip rap, gabions, or dredge-filled geosynthetic tubes to protect from further erosion. In addition Baker recommends collecting, characterizing, and disposing of the small amount of debris which is present on the intertidal beach. Baker also recommends that a routine inspection program be instituted to verify that the interim measures are effective, to measure top of slope encroachment rates and monitor the overall stability of the bank along the landfill.

The 5-gallon container which contains the unknown yellow substance should be removed from the bank, characterized, and disposed properly. These actions will eliminate the possibility of the unknown substance migrating into the York River or adjacent wetland. Characterization of this material will provide information regarding the types of substances disposed in the landfill.

Baker has included the following as attachments to this letter to support the recommendations:

- Photographs of Site 1 showing the actively eroding area, debris on the beach area, and the debris pile adjacent to the marsh associated with the unnamed tributary to the York River

- Excerpts from the US Army Corps of Engineers Part 330 Nationwide Permit Program relevant to emergency shoreline improvements

- Technical information pertaining to filled geosynthetic tubes

The Field Investigation concluded that soil, sediment, and possibly surface water in the vicinity of the landfill have been adversely impacted by previous waste management activities as indicated by elevated levels of polynuclear aromatic hydrocarbons (PAHs), heavy metals, and to lesser extent polychlorinated biphenyls (PCBs) and pesticides. The enclosed report provides recommendations for selecting the appropriate actions for the long-term management of Site 1.

With respect to AOC 2, no apparent site related contamination was detected; however, the geophysical anomalies detected during the investigation are potential indicators of buried metallic objects (such as drums) or other debris. These areas should be further investigated. A limited test pit investigation is recommended in the enclosed report.

In order to maintain the project schedule and meet the proposed date for the Draft Final submission, review comments are requested by April 23, 1999. Baker appreciates the opportunity to provide continued service to LANTDIV and looks forward to continuing these very important project activities at CAX. If you have any comments regarding the enclosed report or the attached documents, please contact me at (412) 269-4687.

Sincerely,

BAKER ENVIRONMENTAL, INC.

Martin G. Taube, P.G.
Project Manager

MGT/lp

cc: Ms. Ollie Glodis. Code 02116 (letter only)
Ms. Carolyn Neill, Code 09E (two copies)
Mr. Dennis Brittin, Code BX0 (letter and attachments only)

Site 1 Photographs

Photograph 1 - (Site 1) View of portion of bank where apparent landfill contents outcrop just below ground surface. Standing on top of banking, looking north. (Debris is not visible in photo).

Photograph 2 - (Site 1) Close up of debris on beach during low tide. Among shell material, apparent incinerated materials and landfill debris (ash, metal, glass, etc) is visible. Standing on beach, looking down.

Photograph 3 - (Site 1) Eroding bank of York River along down stream edge of landfill. Landfill is separated from top of bank by approximately 10 to 20 feet in this area. Standing on beach, looking southwest.

Photograph 4 - (Site 1) View of large debris pile which is adjacent to the marsh area associated with the unnamed tributary to the York River. Standing at toe of pile, looking west.

U.S. Army Corps of Engineers
330 Nationwide Permit Program Excerpts
(Refer to Part 13 - Bank Stabilization and Part 19 - Minor Dredging for Allowable Practices)

Regulatory Program of the US Army Corps of Engineers

Part 330 - Nationwide Permit Program

Final Notice of Issuance, Reissuance, and Modification of Nationwide Permits 13 December, 1996

Nationwide Permits and Conditions

A. Index of the Nationwide Permits and Conditions

Nationwide Permits

1. Aids to Navigation
2. Structures in Artificial Canals
3. Maintenance
4. Fish and Wildlife Harvesting, Enhancement, and Attraction Devices and Activities
5. Scientific Measurement Devices
6. Survey Activities
7. Outfall Structures
8. Oil and Gas Structures
9. Structures in Fleeting and Anchorage Areas
10. Mooring Buoys
11. Temporary Recreational Structures
12. Utility Line Discharges
13. Bank Stabilization
14. Road Crossings
15. U.S. Coast Guard Approved Bridges
16. Return Water from Upland Contained Disposal Areas
17. Hydropower Projects
18. Minor Discharges
19. Minor Dredging
20. Oil Spill Cleanup
21. Surface Coal Mining Activities
22. Removal of Vessels
23. Approved Categorical Exclusions
24. State Administered Section 404 Programs
25. Structural Discharges
26. Headwaters and Isolated Waters Discharges
27. Wetland and Riparian Restoration and Creation Activities
28. Modifications of Existing Marinas
29. Single-Family Housing
30. Moist Soil Management for Wildlife
31. Maintenance of Existing Flood Control Projects
32. Completed Enforcement Actions
33. Temporary Construction, Access and Dewatering
34. Cranberry Production Activities
35. Maintenance Dredging of Existing Basins
36. Boat Ramps
37. Emergency Watershed Protection and Rehabilitation

upon completion of the utility line. (See 33 CFR part 322).

Notification: The permittee must notify the district engineer in accordance with the "Notification" general condition, if any of the following criteria are met:

(a) Mechanized landclearing in a forrested wetland;

(b) A Section 10 permit is required for the utility line;

(c) The utility line in waters of the United States exceeds 500 feet; or,

(d) The utility line is placed within a jurisdictional area (i.e., a water of the United States), and it runs parallel to a streambed that is within that jurisdictional area. (Sections 10 and 404)

13. Bank Stabilization. Bank stabilization activities necessary for erosion prevention provided the activity meets all of the following criteria:

a. No material is placed in excess of the minimum needed for erosion protection;

b. The bank stabilization activity is less than 500 feet in length;

c. The activity will not exceed an average of one cubic yard per running foot placed along the bank below the plane of the ordinary high water mark or the high tide line;

d. No material is placed in any special aquatic site, including wetlands;

e. No material is of the type, or is placed in any location, or in any manner, so as to impair surface water flow into or out of any wetland area;

f. No material is placed in a manner that will be eroded by normal or expected high flows (properly anchored trees and treetops may be used in low energy areas); and,

g. The activity is part of a single and complete project.

Bank stabilization activities in excess of 500 feet in length or greater than an average of one cubic yard per running foot may be authorized if the permittee notifies the District Engineer in accordance with the "Notification" general condition and the District Engineer determines the activity complies with the other terms and conditions of the NWP and the adverse environmental effects are minimal both individually and cumulatively. This NWP may not be used for the channelization of a water of the Unitied States. (Sections 10 and 404)

14. Road Crossings. Fills for roads crossing waters of the United States (including wetlands and other special aquatic sites) provided the activity meets all of the following criteria:

a. The width of the fill is limited to the minimum necessary for the actual crossing;

b. The fill placed in waters of the United States is limited to a filled area of no more than 1/3 acre. Furthermore, no more than a total of 200 linear feet of the fill for the roadway can occur in special aquatic sites, including wetlands;

c. The crossing is culverted, bridged or otherwise designed to prevent the restriction of, and to withstand, expected high flows and tidal flows, and to prevent the restriction of low flows and the movement of aquatic organisms;

d. The crossing, including all attendant features, both temporary and permanent, is part of a single and complete project for crossing of a water of the United States; and,

e. For fills in special aquatic sites, including wetlands, the permittee notifies the District Engineer in accordance with the "Notification" general condition. The notification must also include a delineation of affected special aquatic sites, including wetlands.

This NWP may not be combined with NWP 18 or NWP 26 for the purpose of increasing the footprint of the road crossing. Some road fills may be eligible for an exemption from the need for a Section 404 permit altogether (see 33 CFR 323.4). Also, where local circumstances indicate the need, District Engineers will define the term "expected high flows" for the purpose of establishing applicability of this NWP. (Sections 10 and 404)

15. U.S. Coast Guard Approved Bridges. Discharges of dredged or fill material incidental to the construction of bridges across navigable waters of the United States, including cofferdams, abutments, foundation seals, piers, and temporary construction and access fills provided such discharges have been authorized by the U.S. Coast Guard as part of the bridge permit. Causeways and approach fills are not included in this NWP and will require an individual or regional Section 404 permit. (Section 404)

16. Return Water From Upland Contained Disposal Areas. Return water from an upland, contained dredged material disposal area. The dredging itself may require a section 404 permit (33 CFR 323.2(d)), but will require a Section 10 permit if located in navigable waters of the United States. The return water from a contained disposal area is administratively defined as a discharge of dredged material by 33 CFR 323.2(d) even though the disposal itself occurs on the upland and thus does not require a Section 404 permit. This NWP satisfies the technical requirement for a Section 404 permit for the return water where the quality of the return water is controlled by the state through the Section 401 certification procedures. (Section 404)

17. Hydropower Projects: Discharges of dredged or fill material associated with (a) small hydropower projects at existing reservoirs where the project, which includes the fill, are licensed by the Federal Energy Regulatory Commission (FERC) under the Federal Power Act of 1920, as amended; and has a total generating capacity of not more than 5000 KW; and the permittee notifies the District Engineer in accordance with the "Notification" general condition; or (b) hydropower projects for which the FERC has granted an exemption from licensing pursuant to section 408 of the Energy Security Act of 1980 (16 U.S.C. 2705 and 2708) and section 30 of the Federal Power Act, as amended; provided the permittee notifies the District Engineer in accordance with the "Notification" general condition. (Section 404)

18. Minor Discharges: Minor discharges of dredged or fill material into all waters of the United States provided that the activity meets all of the following criteria:

a. The quantity of discharged material and the volume of excavated area does not exceed 25 cubic yards below the plane of the ordinary high water mark or the high tide line;

b. The discharge, including any excavated area, will not cause the loss of more than 1/10 acre of a special aquatic site, including wetlands. For the purposes of this NWP, the acreage limitation includes the filled area and excavated area plus special aquatic sites that are adversely affected by flooding and special aquatic sites that are drained so that they would no longer be a water of the United States as a result of the project;

c. If the discharge, including any excavated area, exceeds 10 cubic yards below the plane of the ordinary high water mark or the high tide line or if the discharge is in a special aquatic site, including wetlands, the permittee notifies the District Engineer in accordance with the "Notification" general condition. For discharges in special aquatic sites, including wetlands, the notification must also include a delineation of affected special aquatic sites, including wetlands (Also see 33 CFR 330.1(e)); and

d. The discharge, including all attendant features, both temporary and permanent, is part of a single and complete project and is not placed for the purpose of a stream diversion.

e. This NWP can not be used in conjunction with NWP 26 for any single and complete project. (Sections 10 and 404)

* **19. Minor Dredging:** Dredging of no more than 25 cubic yards below the plane of the ordinary high water mark or the mean high water mark from navigable waters of the United States (i.e., section 10 waters) as part of a single and complete project. This NWP does not authorize the dredging or degradation through siltation of coral reefs, sites that support submerged aquatic vegetation (including sites where submerged aquatic vegetation is documented to exist, but may not be present in a given year), anadromous fish spawning areas, or wetlands, or the connection of canals or other artificial waterways to navigable waters of the United States (see 33 CFR 322.5(g)). (Sections 10 and 404)

20. Oil Spill Cleanup: Activities required for the containment and cleanup of oil and hazardous substances which are subject to the National Oil and Hazardous Substances Pollution Contingency Plan (40 CFR part 300) provided that the work is done in accordance with the Spill Control and Countermeasure Plan required by 40 CFR part 112.3 and any existing State contingency plan and provided that the Regional Response Team (if one exists in the area) concurs with the proposed containment and cleanup action. (Sections 10 and 404)

21. Surface Coal Mining Activities: Activities associated with surface coal mining activities provided they are authorized by the Department of the Interior, Office of Surface Mining (OSM), or by states with approved programs under Title V of the Surface Mining Control and Reclamation Act of 1977 and provided the permittee notifies the District Engineer in accordance with the "Notification" general condition. The notification must include an OSM or state approved mitigation plan. The Corps, at the discretion of the District Engineer, may require a bond to ensure success of the mitigation, if no other ederal or state agency has required one. For discharges in special aquatic sites, including wetlands, the .otification must also include a delineation of affected special aquatic sites, including wetlands. (Also

Filled Geosynthetic Tubes Technical Information

DREDGED MATERIAL-FILLED GEOTEXTILE TUBES: DESIGN AND CONSTRUCTION

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ABSTRACT

Long, sometimes continuous, dredged material-filled geotextile tubes have been used in recent years in wetlands and island reclamation projects as well as for groin construction for beach renourishment. In all cases the dredged material-filled tubes were a moderate to low cost, environmentally friendly alternative to traditional materials and provided a "beneficial use" of dredged material.

This paper discusses the current design and construction practices associated with dredged material-filled geotextile tubes and summarizes the lessons learned from recently installed projects.

DREDGED MATERIAL-FILLED GEOTEXTILE TUBES

Overview

Design and construction of geotextile tubes hydraulically filled with a variety of dredged material types has gained popularity in the past few years because of the simplicity of construction of the tubes, their cost effectiveness and their minimum impact on the environment.

Beneficial uses of fine-grained dredged material have been limited because of its high water content, low strength, low angle of repose, and lack of control as to where these materials migrate. Containment of dredged material in geotextile tubes offers a new, significant opportunity for the beneficial use of this fine-grained dredged material.

Dredged Material Filled Geotextile Tubes

System Details. A dredged material filled geotextile tube is a tubular shaped dredged material filled unit. The envelope of the dredged material filled geotextile tube is prefabricated using a soil tight geotextile. A tube with the desired diameter is made out of standard mill widths of geotextile seamed together. The length of the tube is only limited by practical weight limitations. The tube can be delivered to the site rolled up on a pipe, accordion folded, or alternately packaged.

Inlets/outlets are regularly spaced along the length of the tube at intervals appropriate to the settling characteristics of the dredged fill. The inlet/outlet "sock" diameter is somewhat larger than the filling/discharge pipe.

Dredged material filled geotextile tubes are constructed by hydraulic filling of the envelope with a water-soil mixture using a suction dredge delivery line. The dredged material filled geotextile tubes can be pre-filled and placed using a "cradle" bucket on a barge-mounted crane or, more commonly, they can be installed using a continuous position-and-fill procedure.

The dredged material filled geotextile tube is by choice of yarns and fabric construction made in such a way, that:

* sufficient permeability to drain dredged liquids is achieved,
* the dredged fill is retained,
* the tube resists the pressures of filling without rupture, and
* the tube is resistant to erosive forces when filled.

These dredged material filled geotextile tubes will achieve a profile, when properly filled with a steady supply of dredge material under adequate pressure, of up to 70%–80% of the theoretical circular diameter, though 50%–60% is more commonly achieved. Figure 1 provides a schematic of a single tube being filled.

Historical Background. Dredged material filled geotextile tubes have been used as containment dikes in Brazil and France as described by Bogossian, et al. (1982) and Perrier (1986), and more recently in the Netherlands and Germany for both river "training" structures on the river Waal, as reported by ACZ Marine [___(1990)], and as shoreline protection at Leybucht on the North Sea, according to a Nicolon B.V. in-house report [___(1988c)].

Experimentation with dredged material filled geotextile tubes was first tried in Brazil in the early 1980s as a way to construct continuously filled containment dikes for the reclamation of land for housing. In France the technique was used to isolate and contain runoff from a contaminated area.

In 1989 in the Netherlands, ACZ Marine Contractors BV developed the dredged material filled geotextile tube solution for constructing underwater bottom groins for river training. The groins were built up by positioning and stacking pre-filled tubes using a cradle-shaped bucket on a barge mounted crane. Eleven groins were constructed using more than 500 tubes.

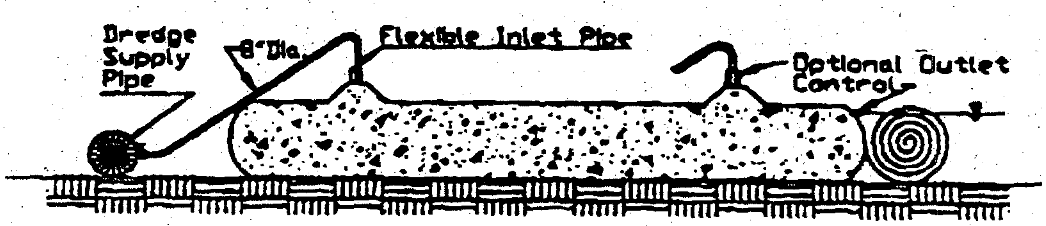


Figure 1. Dredged material filled geotextile tube.

rect filling of geotextile tubes in place using a) dredge delivery line was done with great ss in the project Leybucht on the North Sea in iny in 1988. The continuous tube has provided co...ainment of the fill placed to the inside and protection against currents and waves from the outside.

More recently, as reported by Fowler and Sprague (1993, 1995); Garbarino, et al. (1994); Gill, et al. (1995); Harris (1994); Jorde and Haramis (1995); Landin and Patin (1993); Landin, et al. (1994); Sprague (1993); and Sprague and Fowler (1994), dredge-filled geotextile tubes have been introduced in the United States in the following projects:

Location	Application	Owner
Florida Coast -Destin Harbor -Amelia Island -Multiple Beaches	Shoreline Protection Groins and Revetments	Public and Private
Mobile, Alabama	Dredge Disposal Containment	Corps of Engineers
ston, Texas Bay -Aransus -Port O'Connor -Victoria Canal	Shoreline Protection Breakwater/Disposal Containment	Corps of Engineers
Baltimore, Maryland -Eastern Neck -Smith Island -Honga River -Pokomoke River -Bodkin Island	Shoreline Protection Breakwater/Disposal Containment	Corps of Engineers

DESIGN CONCEPTS FOR GEOTEXTILE TUBES

Introduction

Design concepts for large dredged material filled geotextile tubes and containers are not well documented. Geotextile property requirements are not well ...erstood. Additionally, few details have been re-...l on the operation of dredging equipment and the performance of various types of dredged materials. Still, installations to-date based on "reasoned" design techniques have proven to be quite successful. Therefore, these techniques, as outlined in the following sections, provide a starting point for developing more thoroughly researched design approaches.

Geotextile

The retention of fill and the structural integrity of a dredged material filled geotextile tube is provided by the geotextile envelope. Functionally, fabric selection is based on having opening characteristics which match the fill particle size and permeability and having sufficient strength to resist filling pressures. A composite fabric shell which incorporates both a nonwoven fabric (for filtration) and a woven fabric (for strength) is often used. Figures 2 and 3 provide dynamic filtration and experimentally derived geometrical and tensile strength design guides, respectively.

Dredged Material Fill

The dredged material filled geotextile tubes can be filled with any material capable of being transported hydraulically. Naturally occurring beach or river sand is the preferred choice of fill. However, clayey and silty dredged material has been used for containment dike applications in remote settings where long-term consolidation is a minimal concern. An assessment should be made of the fill material's settling characteristics to assist in the determination of appropriate inlet/outlet spacing. Figure 4 shows how the inlet/outlet spacing is based on fill characteristics.

The longitudinal section shown in Figure 4 shows that if the material is sandy with a steep settling angle, feeding should be done successively through opening A, B, C, and D. Yet, if the fill material is silty with a flatter settling angle, filling is done using only A and D. Figures 5 and 6 provide soil properties for spacing evaluation based on particle sizes and settling rates. According to Goldman, et al. (1986) particle settlement can be calculated using Equation 1. Therefore, Equation 1 can be used along with the figures to determine inlet/outlet spacing.

$$L = Q / (W \times V_s) \qquad (1)$$

where:
- L = inlet/outlet spacing,
- Q = volumetric flow of material,
- W = width of flow, and
- V_s = settling velocity of sediments.

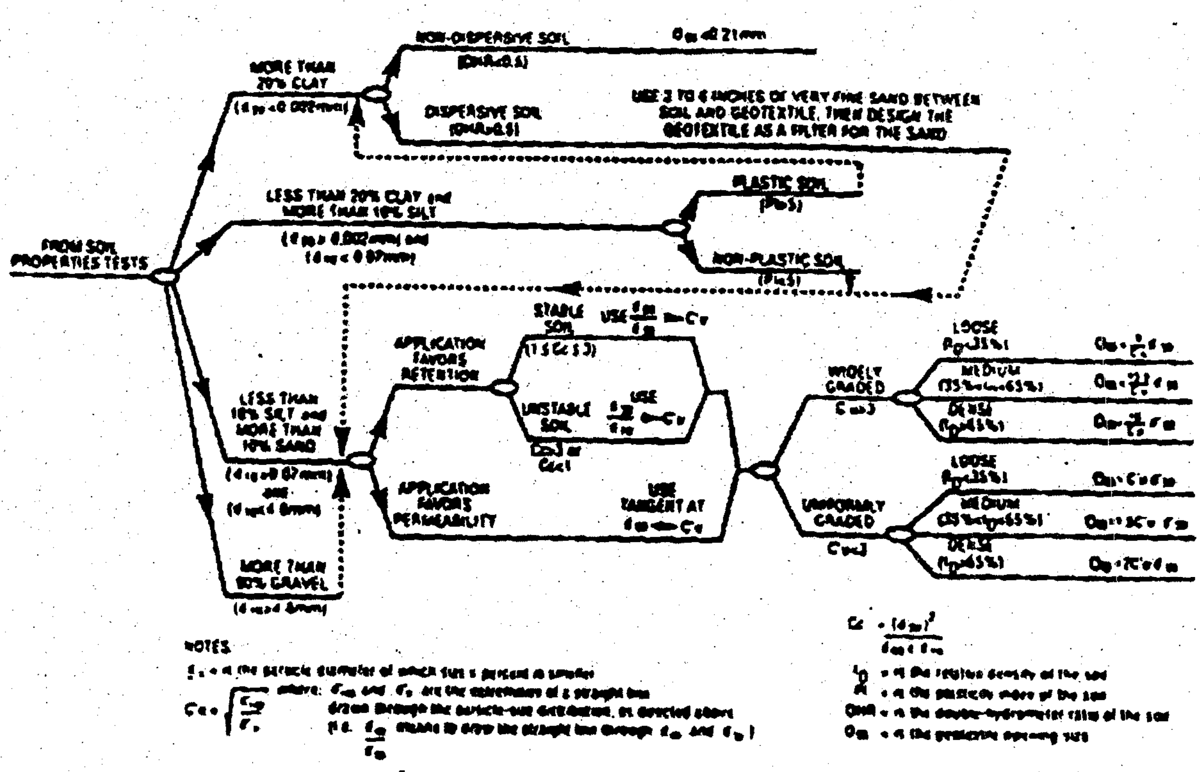


Figure 2. Opening characteristics based on fill soil properties. [After Luettich, et al. (1992)]

Filled Dimensions

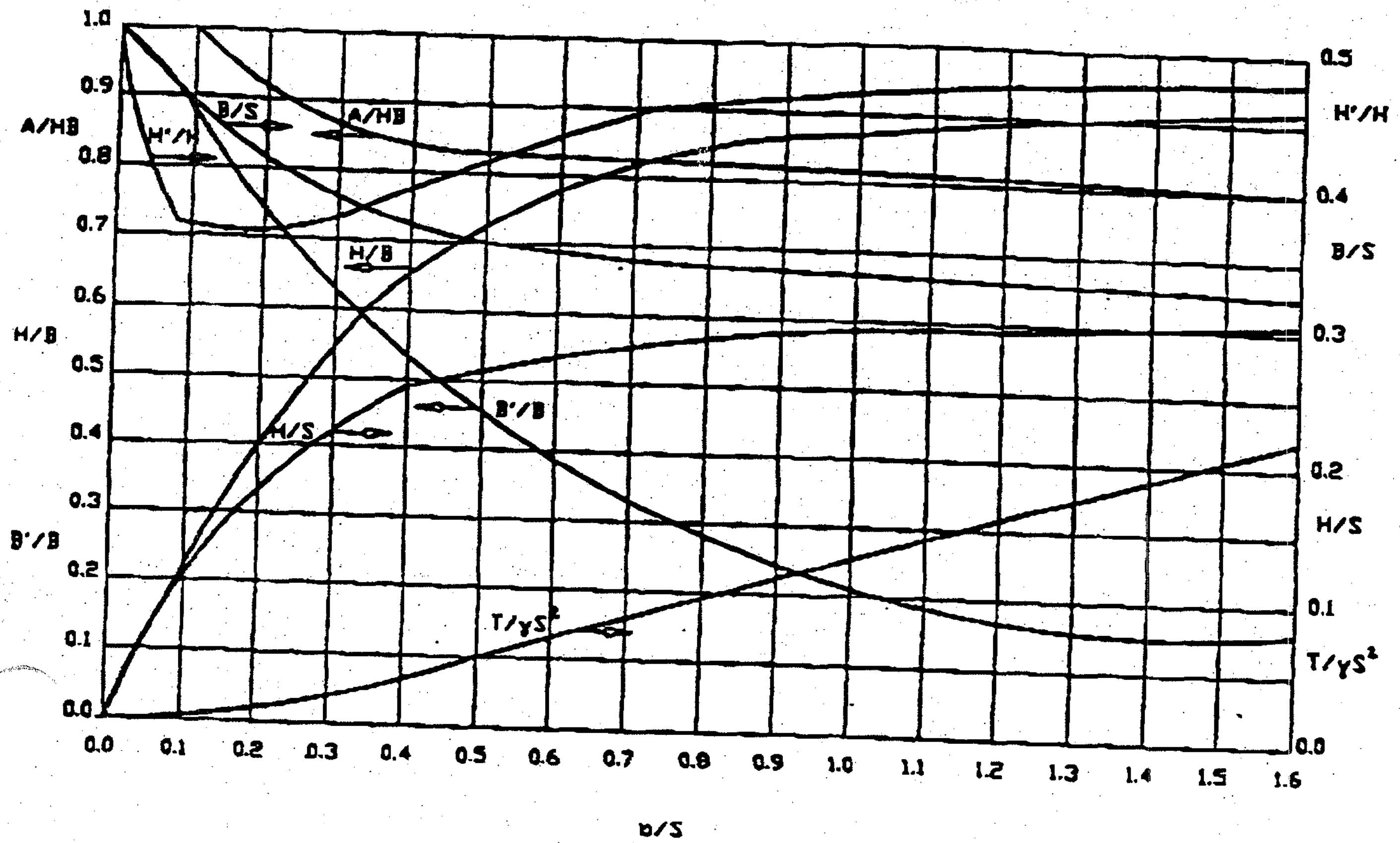
As shown in Figure 3, the analysis of the tube assumes a cross-section which is circular on the edges and flattened on top. Some practitioners, such as Bogossian, et al. (1982) and Perrier (1986), assume the cross-sectional shape of a filled dredged material filled geotextile tube is approximated by an ellipse with a flat top. In either case, field experience has demonstrated that it is possible to fill the dredged material filled fabric tubes to 70 to 80 percent of their theoretical maximum circular diameter though 50–60 percent is more commonly accomplished. Figure 7 gives equations for the approximate determination of tube dimensions using an elliptical model.

Current and Wave Forces

Achieving a relatively high unit weight for a filled unit is essential for stability under severe hydraulic conditions, where drag, lift, and inertia effects can reduce the unit's stability.

In order to assess the stability of the dredge material filled geotextile tube structure, current, and wave forces have to be estimated. Though a definitive analysis technique has not been established, it has been suggested that a modified Miniken approach as outlined in the U.S. Army Corps of Engineers' Shoreline Protection Manual may provide a reasonable approach to assessing the stability of filled units under wave loading. Model tests have shown that the percent of the geotextile tube which is filled with dredged material is an important parameter relating to stability. The internal stability of a "stacked" tube structure is also an important consideration.

Due to current and wave action, the presence of a structure built up by one or more units can lead to a scour hole directly adjacent to the structure, which can



Dimensionless parameters from theory and experiment

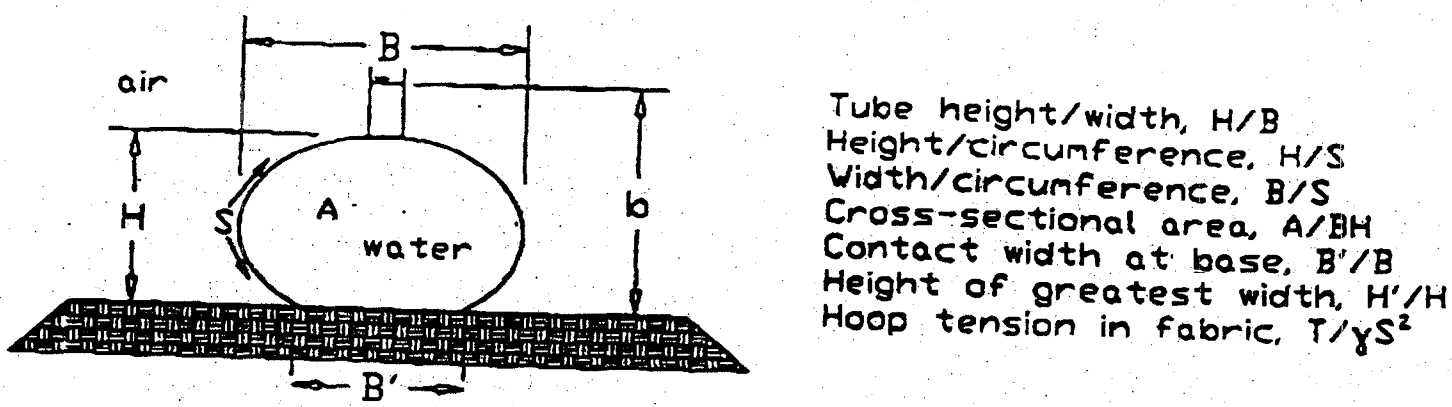


Figure 3. Tensile strength requirements for containment units. [Based on Silvester (1986)]

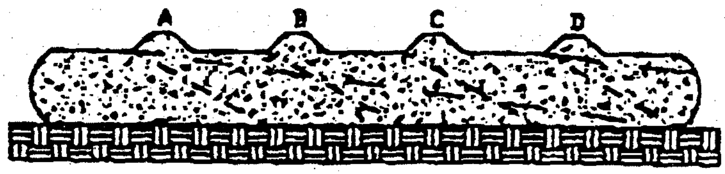


Figure 4. Inlet/outlet spacing based on settling velocity.

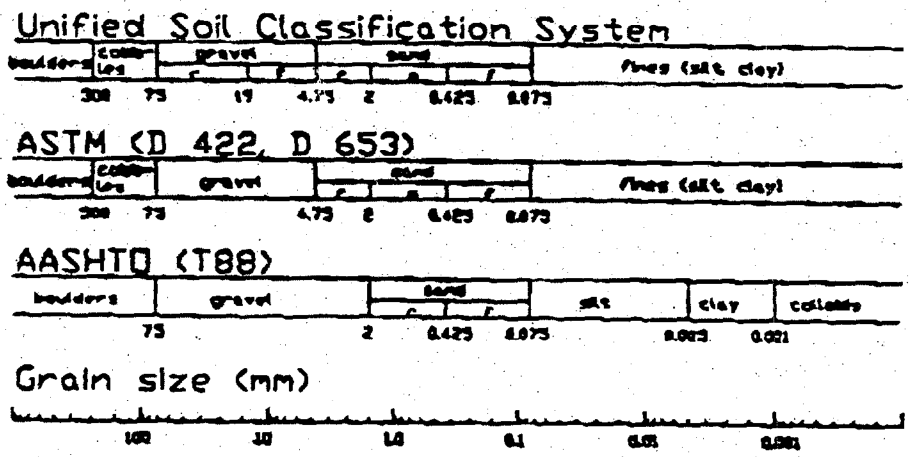


Figure 5. Some common definitions of soils, classified by particle size. [After Carter and Bently (1991)]

result in geotechnical instability of the structure. Therefore, provision must be made for a filter fabric apron for scour protection as shown in Figure 8. The filter fabric apron is often furnished with a "hem" sewn into the perimeter of the apron. The hem is then filled with dredged material to form a continuous soil pillow which holds the edges of the apron in place. The apron must have filtration characteristics which are appropriate for the foundation soil and the soil which fills the hem (reference Figure 2) and should extend in front and behind the unit or structure to a sufficient distance to prevent scour of the foundation, commonly 1–2 times the filled unit or complete structure width.

Foundation

Depending on the subsoil conditions, the possibility of bearing failure has to be taken into account. A tube structure can theoretically be reinforced by a high strength geosynthetic if it can be sufficiently anchored. This reinforced structure could better distribute the soil pressures caused by the weight of the tube structure and eliminate overstressing of the subsoil. Further, the resulting spreading of the vertical load will reduce the settlement of the subsoil. An overview of the potential failure mechanisms of a stacked dredged material filled geotextile tube structure is presented in Figure 9.

Example Design

Given. A tube having 1.2 m of height when filled is required. Fine sand will be used to hydraulically fill the tube. A dredge capable of supplying 0.13 m^3/sec of slurry at 13.8 kPa (1.4 m head) will be used.

Solution. Tube geometry and strength—Assume two 3.8 m wide panels will be used to fabricate the tube. This will provide a circumference, S, equal to approximately 7.3 m (some fabric width is used in the

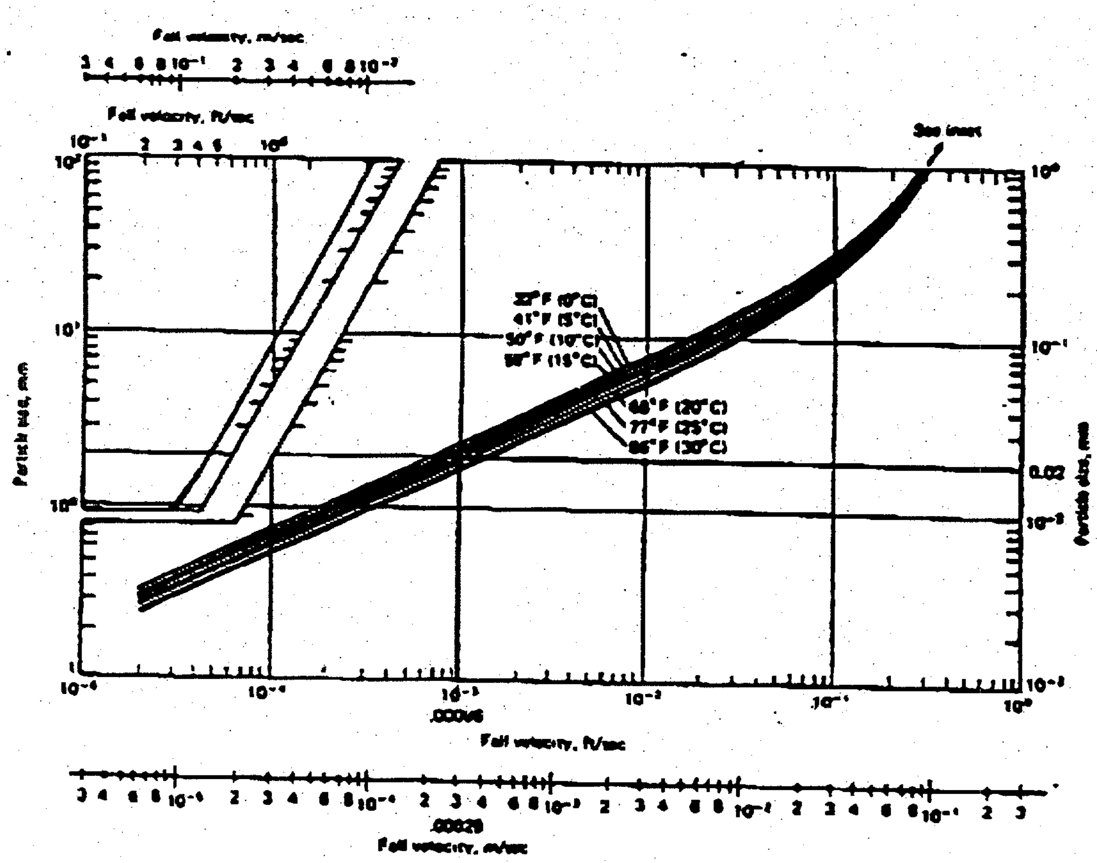
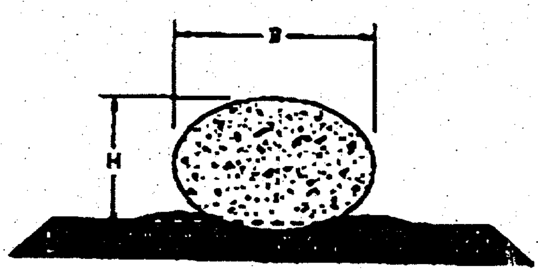


Figure 6. Particle settling velocity curves. [After Goldman, et al. (1986)]



$$A = \pi/4 \; B \; H$$

$$P = \pi/2 \; (B+H) \; \frac{64-3\left(\frac{B-H}{B+H}\right)^4}{64-16\left(\frac{B-H}{B+H}\right)^2}$$

A = cross sectional area of ellipse
P = perimeter of ellipse
B = width of ellipse
H = height of ellipse

Figure 7. Elliptical approximation of tube dimensions. [After Bogossian, et al. (1982)]

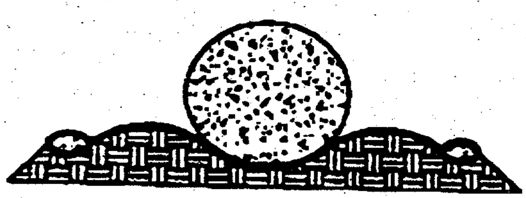


Figure 8. Typical apron for scour protection.

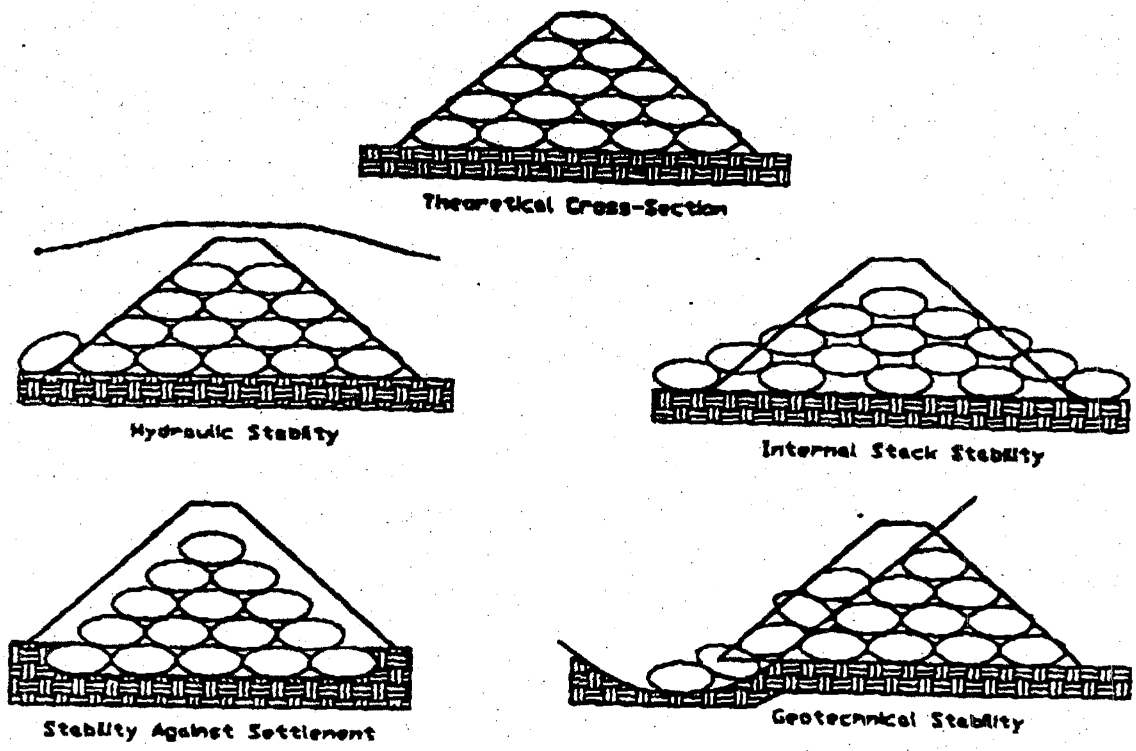


Figure 9. Potential failure mechanisms for stacked tubes.

seam). From Figure 3, for b = H + pressure = 1.2 + 1.4 = 2.6; b/S = 2.6/7.3 = .356 and $T/\gamma S^2 = 0.03$.

Therefore, $T = 0.03(9.8)(7.3)^2 = 16$ kN/m (90 lb/in). A factor of safety of 3.0 for survivability, seam strength and potential creep will bring this value up to 48 kN/m.

Inlet/outlet Spacing—From Figure 5, particle size, d, for fine sand is approximately 0.1 mm. From Figure 6, these particles have a settling velocity, Vs, of 0.0061 m/s (0.02 ft/sec).

Therefore, spacing, L = 0.13/(2.0 x .0061) = 10 m

Tube Specs—Use tubes with FTW = 3.7, having 48 kN/m tensile strength and inlet/outlets spaced every 10 m. (The filtration properties of the tube should be determined based on the fill soil and Figure 2. Also stability of the tubes under wave and current forces should be evaluated.)

DEPLOYMENT AND FILLING

Tubes—"In-the-dry"

Site Preparation. Before deployment of the tube, a shallow trench is made which is lined with a plastic film to keep water from washing soil away or weakening soil beneath the tube while it is filled. A filter fabric rather than plastic film may be used when the supporting soils are not significantly water sensitive.

Positioning the Tube. The tube is rolled out along the intended alignment with inlets/outlets centered on top. Only the length intended to be filled at one time should be deployed. The tube should be "tied-off" at the end of each length to be filled slightly beyond an outlet.

Discharge Connection. If the settling characteristics of the fill soils require multiple inlets, install an elbow and pipe extension in the succeeding fabric inlet/outlet to allow for controlled removal of water the pumping process. The fabric outlet is tightly ...d to the discharge pipe to prevent leakage. The ...xtension may be supported by an "A-frame" or ...arable equipment capable of raising and lowering the discharge during filling to regulate pressure within the tube.

Inlet Connection. The filling pipe is connected into the fill inlet. The pipe that leads into the tube must be flexible enough to avoid mechanical damage to the fabric during the pumping process, yet rigid enough to provide unrestricted flow. The fabric inlet is secured tightly around the filling pipe to prevent leakage. The filling pipe must be supported by an "A-frame" or other comparable structure to prevent misalignment under pressure and to assist in removal of the pipe at the completion of tube filling.

Dredge Line Connection. For pumping purposes, a branch line—commonly 20 centimeters in diameter—with a slide valve is connected to the main line. The main line runs to the dredge across a system of floats.

Tube Filling. The pumping process should not be interrupted. By opening the slide valve, dredge material ... allowed to flow to the tube through the branch ...e actual rate of filling will depend on the granu...ze and weight of the dredge fill as well as the ...r content of the slurry. A granular size of 0.10 mm is the preferred pumping material. The dredge fill is commonly pumped in a slurry of 1:4. The water escapes through the fabric and, if required, through the outlets spaced at intervals along the tube. Based on experience, the filling of a 400 meter long tube with fine sand using outlets located every 75 meters takes about 5 hours.

Controlling the Filling. A crane or other "boom" equipment capable of raising and lowering is used to properly position both the inlet and outlet pipes. The inlet pipe must be securely positioned to prevent misalignment while the outlet pipe must be raised or lowered to regulate internal tube pressure. The lifting equipment is also used to assist in the connect/disconnect procedure which is cumbersome when pipes are filled with water and/or sediments.

Extending Tubes. The tubes, which are commonly less than 100 meters in length but may be several hundred meters long, may be connected to each other, at the site, by vendor approved joining techniques. ...natively, and more commonly, the tubes can ...p each other by approximately 3 m side-by-side ...rmitted by the alignment.

Tubes—Below Water Line

When a tube is to be placed below the water line, the effects of buoyancy on the tube geotextile prior to filling as well as on the dredged material's settling characteristics must be considered. In order to maximize inlet/outlet spacing, an outlet distant from the inlet may be used to enhance the discharge of dredged liquids and thereby encourage and regulate the flow of fill material through the tube so that sufficient fill will flow to distant points.

Commonly, the filter fabric scour apron and flat tube are fully deployed by floating and holding them in position prior to beginning the filling operation.

GEOTEXTILES FOR TUBES

Currently Used Geotextiles

Geotextiles in Use. Many different types of geotextiles have been fabricated into large bag, tube, and container structures. Woven nylon, polyethylene, polypropylene, polypropylene/polyester, and nonwoven polyester fabrics have all been used on various projects since the 1960s. Some systems have coated the fabric with PVC to create an impermeable membrane and to enhance longevity. Table 1 details the most common geotextiles currently used for tube construction.

Deficiencies. To-date dredged material-filled geotextile tubes have been used with modest success while still presenting significant promise. Recently installed geotextile tubes have shown the following apparent deficiencies:

- Poorly made/designed seams have failed under the pressures of filling, especially in and around the inlet.
- Tubes filled with coarse material experienced premature settling and the consequent uneven top elevation. More frequent inlets were necessary to minimize the impact of quick settling of sediments.
- Tubes filled with fine material can be filled with few, widely spaced inlets yet they retain large quantities of water as a result of fine-grained soils "caking" on the inside of the tube and limiting the ability of dredged liquids to drain efficiently. Subsequent refilling of tubes is required to attain the desired long-term tube elevation. An associated problem involves the overfilling of these tubes.

causing them to "balloon" and exert excessive stresses on the geotextile.

- Concerns over the durability or long-term performance of the geotextile shell have largely been ignored in the interest of demonstrating the filling process. Unanswered concerns include the U.V., abrasion and vandalism resistance of the geotextile and the consequent effects of large losses of fill as well as floating pieces of the geotextile. Also, creep of the geotextile shell result in reduced elevation of the tube has yet to studied.

- More often than not, when a problem occurs filling the tubes it is a result of insufficient or exce sive dredged material supply. Clearly, consiste dredged material supply with a valved diversi discharge near the tube inlet allows for maximu control of the filling operation.

Table 1. Currently Used Geotextiles for Tube Construction.

	U.S.		European
	Woven (shell) + Nonwoven (liner)		Woven only
Wide Width Strength, kN/m (ASTM D 4595)	70 x 70	175 x 175	87 x 87
Wide Width Elongation, % (ASTM D 4595)	20 x 20	10 x 10	25 x 20
A.O.S., mm (ASTM D 4751)	0.210	0.250	0.100
Water Flow Rate, l/s/m² (ASTM D 4491)	27	-	10
Seam Strength, kN/m (ASTM D 4595)	44–61	87	52
Raw Materials—Shell:	PP Mono. x PP Fibr.	PET Multi. x PET Multi.	PE Mono. x PET Multi.
—Liner:	PET, CF, NP, NW	PET, CF, NP, NW	
Liner/Shell Connection	Tied 1 m c–c	Tied 1 m c–c	n/a
Approx. Cost, $/m² —Shell	1.80	6.00	2.50
—Liner	0.60	0.60	n/a

Future Geotextiles for Tubes

P.E.T. Potential. P.E.T. geotextiles offer potential answers to lingering concerns about geotextile tubes. The unique attributes of P.E.T. geotextiles that can benefit dredged material-filled tubes include:

- Maximum strength to weight ratio provides extra factor of safety against tensile failure of the shell.
- Maximum creep resistance assures long-term geometric stability.
- Inherent U.V. and abrasion resistance enhances longevity in demanding environments.
- High specific gravity assures geotextile fragments will readily sink and not be a threat to wildlife.

Composite Geotextile Potential. Dredged material-filled geotextile tubes have been fabricated out of nonwoven geotextiles, woven geotextiles, and one layer each of nonwoven and woven geotextiles. Each of these constructions has proven successful, yet each has been less than optimal. Specifically, nonwoven tubes stretch circumferentially significantly more than woven tubes during filling which requires nonwoven tubes to have a greater circumference to achieve a given elevation. Woven tubes provide lower circumferential strain and, therefore, a more efficient means to attain higher elevations. Yet, wovens lack the balance of filtration properties, namely soil retention and permeability, which allow the tubes to retain the solids in the dredged material while efficiently expelling the water.

Clearly, a combination of both nonwoven and woven geotextiles has the potential to provide *both* the strength to achieve desired geometries with the least amount of material and the filtration characteristics to maximize the solids retention within the tube in the least amount of time. Tubes used recently in the U.S. have consisted of one layer each of nonwoven and woven geotextiles. Once "inflated," the tubes have performed admirably. Yet, some difficulty has been experienced during the filling process when the liner is not connected to the shell and has separated from the shell and become folded and pinned beneath fill material preventing the liner from conforming to the desired geometry.

Therefore, the natural next innovation is to provide for a positive and continuous connection between the two layers which will prevent separation of the layers.

SUMMARY AND CONCLUSIONS

Summary of Technical Issues

This paper outlines the feasibility, applicability, and brief experience record of hydraulically filled-in-place "tube" systems for the construction of earthen mounds such as containment dikes and groins.

Tube Systems. Geotextile tubes, i.e., hydraulically filled prefabricated units, are used for construction of earthen mounds such as containment dikes and groins both above and below the waterline. The major design considerations include sufficient geotextile fabric and seam strength to resist pressures during filling and placement impact, and fabric/soil compatibility (i.e., filtration characteristics). Additional considerations include long-term U.V. resistance; resistance to abrasion, tearing and puncturing (including vandalism); and tube flattening resulting from the consolidation of sediments within the tube or geotextile creep.

Technical Conclusions. The tube technology outlined in this report offers the potential for the construction of low-cost earthen mounds out of readily available materials. These mounds offer the versatility to be virtually any size or shape simply by stacking additional tubes. The following areas are potential applications of dredged soil containment systems using tubes:

1. Remote dike and levee construction for disposal islands, beach renourishment, and wetlands reclamation.
2. Lateral erosion control structures such as groins and jetties.
3. Containment, placement, and long-term confinement of contaminated materials.
4. Underwater capping of contaminated materials.
5. Accelerated dewatering of fine grained dredged material.

Dredged material-filled geotextile tubes have been utilized extensively in Europe and to a lesser extent in the U.S., producing successful installations but few technical details. The technology has been shown to be feasible but there are design and constructibility uncertainties that must be addressed through further full-scale monitored installations.

Summary of Commercial Issues

In the past 3 to 4 years, dredged material-filled geotextile tubes have been demonstrated to be commercially viable with at least 10 projects having been constructed. This technology is quickly emerging from "experimental" status to the status of commercial viability.

The U.S. Army Corps of Engineers has been the driving force behind most of the tube projects to-date. Most of these projects have involved the beneficial use of dredged material. This means that sediments that must be dredged from shipping channels can be used for some mutually beneficial use rather than simply disposing of the material using traditional means. Re-creation of wetlands using dredged material-filled tubes as containment dikes or breakwaters is a popular "beneficial use." Though all recently reported projects have shown that tubes can be successfully installed, some projects have experienced difficulties which required finding an alternative dredged material source, altering the dredging and/or material conveyance system, or replacing tubes which failed during filling.

A recently completed research program focused on tubes and other geotextile containers under the Corps of Engineers' Construction Productivity and Research (CPAR) program. The findings of the program should provide more definitive design and installation guidance.

Interestingly, polyester has emerged as the most environmentally sensitive, yet durable material for the construction of tubes and containers. A 100% PET geotextile possessing both nonwoven-like (good filtration) and woven-like (high strength) characteristics appears to offer superior potential, compared to currently available geotextiles, for the fabrication of dredged material-filled geotextile tubes.

REFERENCES

——— (1988c). "Coastal Protection in the Leybucht, North Sea Coast, West Germany." In-house Report, Nicolon BV, the Netherlands.

——— (1990). "Applications and Execution Aspects of Sand Tube Systems." In-house Report, ACZ Marine Contractors BV, the Netherlands.

Bogossian, F., R. T. Smith, J. C. Vertimatti, and O. Yazbek. (1982). Continuous Retaining Dikes by Means of Geotextiles, Proceedings of the Second International Conference on Geotextiles, Las Vegas, p. 211–216.

Carter, M., and S. P. Bently. (1991). Correlations of Soil Properties. Pentech Press Limited, London, U.K., p. 4.

Fowler, J., and C. J. Sprague. (1993). Dredged Material Filled Geotextile Containers. Proceedings of Coastal Zone '93, ASCE, p. 2415–2428.

Fowler, J., and C. J. Sprague. (1995). Dredged Material Filled Geotextile Containers. *Waterfowl Habitat Restoration, Enhancement and Management in the Atlantic Flyway.* Third Ed., Environmental Management Committee, Atlantic Flyway Council, Technical Section, and Delaware Division of Fish and Wildlife, P.O. Box 1401, Dover, Del., p. K83–K95.

Garbarino, S. D., R. N. Blama, M. C. Landin, S. R. Maynord, and T. R. Patin. (1994). Environmental Restoration and Enhancement Using Dredged Material in Chesapeake Bay, Maryland. Proceedings of Dredging '94, ASCE, p. 384–393.

Gill, J. W., P. McGowan, and L. Pitt. (1995). Beneficial Uses of Dredged Material for Habitat Restoration, Case Study: Eastern Neck Island National Wildlife Refuge Wetland Creation and Erosion Control Project. *Waterfowl Habitat Restoration, Enhancement and Management in the Atlantic Flyway.* Third Ed., Environmental Management Committee, Atlantic Flyway Council, Technical Section, and Delaware Division of Fish and Wildlife, P.O. Box 1401, Dover, Del., p. E65–E104.

Goldman, S. J., K. Jackson, and T. A. Bursztynsky. (1986). Erosion & Sediment Control Handbook, McGraw-Hill, p. 8.11.

Harris, L. E. (1994). Dredged Material Used in Sand-filled Containers for Scour and Erosion Control. Proceedings of Dredging '94, ASCE, p. 537–546.

Jorde, D. G., and G. M. Haramis. (1995). Water/Dredge-filled Tubes: A New Level of Flexibility for Wetland Managers, *Waterfowl Habitat Restoration, Enhancement and Management in the Atlantic Flyway.* Third Ed., Environmental Management Committee, Atlantic Flyway Council, Technical Section, and Delaware Division of Fish and Wildlife, P.O. Box 1401, Dover, Del., p. K71–K82.

n, M. C., and T. R. Patin. (1993). Innovative Wet-nds in Urban Settings Using Dredged Material. xceedings of Water Management in the '90s, ,CE, p. 109–112.

.andin, M. C., J. Fowler, and H. H. Allen. (1994). New Applications and Practices for Beneficial Uses of Dredged Material. Proceedings of Dredging '94, ASCE, p. 526–536.

Luettich, S. M., J. P. Giroud, and R. C. Bachus. (1992). Geotextile Filter Design Guide. Geotextiles and Geomembranes, Vol. 11, Nos. 4–6, p. 355–370.

Perrier, H. (1986). Use of Soil-filled Synthetic Pillows for Erosion Protection. Proceedings of the Third International Conference on Geotextiles, Vienna, p. 1115–1119.

Silvester, R. (1986). Use of Grout-filled Sausages in Coastal Structures. Journal of Waterway, Port, Coastal, and Ocean Engineering, ASCE, Vol. 112, No. 1, p. 95–115.

Sprague, C. J. (1993). Dredged Material Filled Geotextile Tubes, Mobile District, Report to U.S. Army Engineer CEWES-CT.

Sprague, C. J., and J. Fowler. (1994). Dredged Material-filled Geotextile Containers: Case Histories, Research and Upcoming Workshop. Geotechnical Fabrics Report, October/November, p. 42–54.

Geotex®
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GEOTEX® REPORT

A Geotextile Case Study From Synthetic Industries

Geotextile Tubes Used To Combat Beach Erosion

Background

A series of strong coastal storms wreaked havoc on a South Jersey shoreline consuming a wide path of heavily vegetated dunes, and more than a dozen yards of beachfront separating a three-story condominium complex from the raging sea. The aftermath left this 18-unit complex in Sea Isle City, New Jersey defenseless should another series of storms strike the shoreline. With several months of winter storms ahead, and no signs of El Nino relenting, City officials were gravely concerned with saving this beachfront property and other surrounding real estate.

,troduction

Designed to protect shoreline beaches from the devastation caused by these coastal storms, high strength geotextile tubes are the latest in protection against the erosive forces of nature that occur every time waves, high tides and longshore currents collide with a vulnerable stretch of beach. These tubes are constructed of high strength polyester and filled with dredged material, or trucked-in sand (as in the case of Sea Isle City). Once filled, the tubes are covered with sand, creating a resilient base for dunes to protect against erosion and storm damage.

Geotextile tubes are designed to resist abrasion, tearing, and puncturing, as well as endure pressure during filling and placement. Traditional materials, such as rock or concrete, can be ten times more expensive than the use of geotextile tubes. "The tubes are more easily removed, have a finite lifespan, and can have a far less permanent impact on the environment than conventional hard structures," stated Orrin Pilkey, director of Duke University's Study of Developed Shorelines.[1]

Construction

Albrecht & Heun, the General Contractor, kicked off the project to restore the shoreline between 91st and 93rd Streets only) weeks after the devastation to the Sea Isle City's shoreline .curred. With the aid of front-end loaders, backhoes, dump trucks, and hydraulic equipment, Heun's six-man crew began working to install 900 feet of **Geotex® 12x12** tubing, manufactured by Synthetic Industries (SI), with hopes of protecting the condominium complex from future storm damage.

Coastal storms washed away beachfront to within feet of the condominium structure.

During the first week, workers constructed a temporary road to the beach and began hauling in equipment for the replenishment and filling of the **Geotex® 12x12** tubes. A crane lifted rocks and debris from the site so that the tubes could be placed on the beach without the possibility of puncture to the tubing.

The tube rests on a polypropylene scour apron that serves to inhibit undercutting of the tube's foundation if the sand layer is removed by future storms. In the Sea Isle City project, **Geotex® 4x4** was specified in the construction of the scour apron.

The process began with a trapezoidal trench 1 foot below grade, onto which the apron was placed. The scour apron also serves to reduce local erosion caused by the flow of water during the filling process. Three tubes, 30 feet in circumference, were then set on the apron and a sand and water slurry was trucked and pumped into the tubing using an IMS submerged cutterhead dredge, through a 10" discharge line. The water percolates out through the fabric, leaving a dense sand-filled structure.

The tube was then pumped until full, with heights reaching 5.5 to 6 feet and widths of 12 to 13 feet. The feet of tubing contained nearly 00 cubic yards of sand when full. After the tube was completely filled, it was covered with an additional 1 to 2 feet of sand, creating an 8-foot high dune along the beach.

Right – Filling Geotex® tube with slurry of sand and water.

Geotex® tube partially covered.

As is often the case, tests at Sea Isle City showed that some percentages of the fill material were smaller than the opening size of the fabric. Experience has proven that polyester fibers and yarns tend to expand when soaked and under pressure, making the openings smaller, thus retaining nearly all of the fill material. The role of surface tension in retaining material can be observed when walking on the tube during filling. Additionally, it is believed that material cakes on the inside of the fabric casing, retaining even fine-grained materials. These filtration qualities have led to an additional use of tubes for dewatering of industrial waste and the containment of contaminated materials.

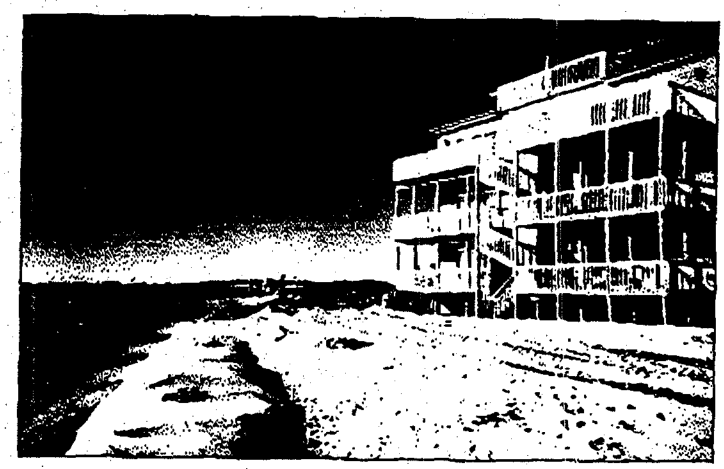
Conclusions

The **Geotex® 12x12** tube will remain on the beachfront for an indefinite period of time. Along the landward side of the tube, the wide berm of sand placed by the crew is intended to develop into a dune, working against the force of the sea to protect valuable beachfront property.

Within three weeks, the tubing had been successfully placed, restoring valuable shoreline and protecting the 18-unit complex from becoming one with the sea. City officials were pleased with the $163,398 investment in their ongoing struggle against beach erosion.

According to Michael Bruno, a coastal engineering expert at Stevens Institute of Technology, "They are remarkably cheap. When you compare it to stone, not to mention the stress that rocks put on the infrastructure, it is much more inexpensive. There are a number of reasons why it is better from a practical construction sense."[2]

Three months after installation, the tubes were put to an extreme test when northeast storms once again slammed into the New Jersey shoreline. Cape May County was declared a national disaster area as a result of these storms. The tubes held and, while the sand was lost behind the tubes, the condominium complex was not damaged. The success of this and other projects will aid engineers and contractors in reclaiming our shorelines and stemming erosion.



After installation of the tube, fill was replaced seaward of the condominium.

References:

[1]The Philadelphia Inquirer, December 8, 1997
[2]The Philadelphia Inquirer, December 8, 1997

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